SP-F8 Transfer of Energy and Nutrients by Anadromous Fish Migrations

October 25, 2002

1.0 Introduction/Background

Pacific salmon ecology studies illustrate the importance of the anadromous salmonids in the transport of nutrients and organic matter to the freshwater aquatic ecosystems where they spawn. Preying and Chinook scavenging by terrestrial organisms on the salmonids, eggs, and carcasses result in the enrichment of terrestrial habitats as well Chinook (Cederholm et al. 1999; Gresh et al., 2000; Bilby et al. 2001).

The construction of the Fish Barrier Dam, the Thermalito Diversion Dam, and Oroville Dam (herein collectively called the Oroville Facilities) inhibits the migration of Chinook salmon and steelhead to the historical spawning grounds in the tributaries of the Feather River located upstream of Lake Oroville (also called the upstream tributaries). This results in the removal of the salmonids as a source of energy and nutrients in these habitats and potentially reduces the productivity of the aquatic and terrestrial ecosystems.

This study plan is designed to address the effects of the Oroville Facilities operations on the nutrient and organic matter transfers to the upstream tributaries. To this end, escapement estimates for the upstream tributaries will be developed based on two separate methodologies. First, historical escapement surveys for the upstream tributaries will be reviewed to provide estimates of the number of salmon contributing to the upstream transfer of nutrients and organic matter prior to the construction of the Oroville Facilities. Second, potential escapement estimates will be developed based on the current available salmonid spawning habitat in the upstream tributaries and spawning densities from the spawning grounds downstream of Lake Oroville. Neither escapement estimate is designed to definitively determine the nutrients lacking from the upstream tributaries, but instead is designed to provide a range of estimates and baseline information useful for facilitating a dialog regarding appropriate nutrient mitigation techniques for the upper tributary environments.

2.0 Study Objective

The objective of this study plan is to collect baseline information to evaluate the effect of ongoing blockage of the upstream transfer of salmonid-derived nutrients and organic matter to the upstream tributaries. The resulting information will be used to develop and evaluate potential future PM&Es.

Individual task objectives include:

- Task 1: Document, review, and summarize the available literature regarding historical escapement of anadromous salmonids in the tributaries upstream of Lake Oroville;
- Task 2: Estimate the potential maximum escapement of salmonids given the existing habitat of the tributaries upstream of Lake Oroville;
- Task 3: Document, review, and summarize the existing literature regarding the types and amounts of nutrients and organic matter supplied by salmonid spawning and the nutrient transfer strategies from other investigations.

3.0 Relationship to Relicensing/Need for the Study

This study is needed because project facilities currently inhibit the upstream movement of anadromous fish stocks and may therefore potentially affect the transfer of fish-derived nutrients and organic matter to the tributaries upstream of Lake Oroville. The potential influence on the nutrient transfer may contribute to a general decrease in productivity in the aquatic and terrestrial ecosystems of the upstream tributary basins. For example, results of water quality tests in the North, Middle and South Forks of the Feather River indicate relatively low levels of limiting nutrients such as phosphates and nitrates (DWR 2001). However, focused studies on the Feather River investigating the relationship between blockage of anadromous salmonid passage and nutrient and organic material levels in the upstream tributaries have never been conducted.

The potential loss of ecological productivity due to the elimination of the anadromous Chinook salmon and steelhead runs from the Feather River Basin upstream of Oroville Dam represents a continuing impact of the project on the biological resources of the area. Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the FERC Application for License for major hydropower projects, including a discussion of the fish, wildlife and botanical resources in the vicinity of the project. The discussion needs to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operation of the project. In addition to fulfilling these requirements, the specific investigations developed in this study plan will also be used in determining PM&E measures.

4.0 Study Area

Four major tributaries exist upstream of Lake Oroville including the North Fork Feather River, the West Branch of the North Fork Feather River, the Middle Fork Feather River, and the South Fork Feather River. The proposed study area is defined as the reaches of these tributaries existing between Lake Oroville's high water mark and the first salmonid migration barrier in each tributary. Previous investigations of tributary spawning potential have identified Miocene Dam on the West Branch of the North Fork Feather River, Curtain Falls on the Middle Fork Feather River, and Ponderosa Diversion Dam on the South Fork Feather River as impassable fish barriers, and Big Bend Dam on the North Fork Feather River as an impediment to upstream passage at all but the highest reservoir levels (DWR 1993). However, Task 1A of SP-F3.1 will provide the most current data regarding barriers to migrating salmonids in the tributaries upstream of Lake Oroville. Smaller tributaries in the upstream drainages include Berry Creek, Canyon Creek, Chino Creek, Concow Creek, Fall River, French Creek, Frey Creek, Sucker Run Creek, McCabe Creek and Stony Creek. The portions of the smaller-order tributaries accessible to spawning salmonids will also be included in the analyses described in this study plan.

Study plans approved by the Environmental Work Group define the limits of the study area. If initial study results indicate that the study area should be expanded or contracted, the Environmental Work Group will discuss the basis for change and revise the study area as appropriate.

5.0 General Approach

This study is designed primarily as a desktop investigation to assemble and summarize information regarding historical escapement levels of salmonids in the tributaries upstream of Lake Oroville, potential escapement given the current habitat conditions in the upstream tributaries, the nutrient and organic matter levels derived from the salmonid escapement, and the nutrient mitigation alternatives, results, and potential implementation issues. At this time, a field study component is not necessary to fulfill the study objectives, however field data will be obtained from SP-F3.1 (habitat mapping of the tributaries upstream of Lake Oroville) and SP-F10 (spawning densities downstream of Lake Oroville). The study plan is structured as a three-task study. If initial study results indicate that the methods and tasks should be modified, the Environmental Work Group will discuss the basis for change and revise the study plans as appropriate.

In Task 1, a literature review will be conducted to estimate the historical escapement of salmonids into the reaches of the Feather River upstream of the existing Oroville Facilities. In Task 2, habitat mapping information (obtained from SP-F3.1) and spawning density calculations (obtained from SP-F10) will be utilized to determine an estimated potential maximum level of escapement into the upstream tributaries, assuming full habitat utilization. Task 3 will provide a literature review and summary of the types and amounts of nutrients and organic matter derived from salmonid carcasses and spawning byproducts and the results of other nutrient transfer strategies.

The study plan is organized into the following three tasks:

1. Document, review, and summarize the available literature regarding historical escapement of anadromous salmonids in the tributaries upstream of Lake Oroville;
2. Estimate the potential maximum escapement of salmonids given the existing habitat of the tributaries upstream of Lake Oroville;
3. Document, review, and summarize the existing literature regarding the types and amounts of nutrients and organic matter supplied by salmonid spawning and the nutrient transfer strategies from other investigations.

In order to achieve the final objective of collecting baseline information to serve as a foundation for the development and evaluation of potential future PM&Es, information from many sources must be integrated and summarized. The literature review may include, but is not limited to, the following existing sources:

- Annual population estimates for fall and spring run Chinook salmon returning to spawn. Surveys conducted by DFG (using various methods) every fall since 1954
- Initial hatchery production goals from the annual reports from the Feather River Hatchery (Interim) Facility, CDFG, Inland Fish Administration.
- DFG. 1952. Fisheries problems of the Feather River with special reference to the proposed Oroville Dam. October 30, 1952.
- Yoshiyama, R. M., E. R. Gerstung, F. W., Fisher, and P. B. Moyle. 1996. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Dep. Wild, Fish, and Conservation Biology, 54p. (Available from Dept. of Wildlife, Fish, and Conservation Biology, University of California, Davis, CA 95616.

- Evermann, Barton Warren and Howard Walton Clark. 1931. A distributional list of the species of freshwater fishes known to occur in California. California Department of Fish and Game, Fish Bull. 35. 67 p.
- Fry, Donald H. 1961. King salmon spawning stocks of the California Central Valley, 1940-1959. California Department of Fish and Game, 47(1):55-71.
- Warner, George H. 1955. The relationship between flow and available salmon spawning gravel on the Feather River below Sutter Butte Dam. California Department of Fish and Game, Mar. Res. Office Rep. 6 p. (mimeo.)
- Warner, George H. (Unpublished). Studies on the downstream migration of young salmon in the Feather River. California Department of Fish and Game. 1955. 5 p. plus appendices (mimeo.)
- Wooster, T. W. 1966. A report to the California State Water Rights Board on the fish and wildlife resources of the Feather River to be affected by the Oroville Dam and Reservoir, Thermalito Diversion, Thermalito Forebay, and Thermalito Afterbay and measures proposed to maintain these resources. California Department of Fish and Game, pg. 29.
- Ben-David, M., T.A. Hanley, and D.M. Schell. 1998. Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. Oikos 83:47-55.
- Cederhold, C. J., D.B. Houston, D.L. Cole, and W.J. Scarlett. 1989. Fate of coho salmon (*Oncorhynchus kisutch)* carcasses in spawning streams. Canadian Journal of Fisheries and Aquatic Sciences 46:1347-1355.
- Johnston, N.T., J.S. MacDonald, K.J. Hall, and P.J. Tschaplinski. 1997. A preliminary study of the role of sockeye salmon (*Oncorhynchus nerka*) carcasses as carbon and nitrogen sources for benthic insects and fishers in the "Early Stuart" stock spawning streams, 1050 km from the ocean. British Columbia Ministry of Environment, Lands and Parks, Fisheries Project Report RD55, Victoria.
- Larkin, G. and P.A. Slaney. 1997. Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries 22(11):16-24.
- Michael, J.H., Jr. 1998. Pacific salmon escapement goals for the Skagit River watershed as determined by nutrient cycling considerations. Northwest Science 72:239-248.
- Richey, J.E., M.A. Perkins, and C.R. Goldman. 1975. Effects of kokanee salmon (*Oncorhynchus nerka*) decomposition on the ecology of a subalpine stream. Journal of the Fisheries Research Board of Canada 32:817-820.
- Schuldt, J.A. and A.E. Hershey. 1995. Effect of salmon carcass decomposition on Lake Superior tributary streams. journal of the North American Benthological Society 14:259-268.
- Concurrent studies occurring as part of the Oroville Facilities FERC relicensing process.

Detailed Methodology and Analysis Procedures

Task 1— Document, review, and summarize the available literature regarding historical escapement of anadromous salmonids in the tributaries upstream of Lake Oroville

Task 1 will consist of a review and summary of the historical Chinook salmon and steelhead escapement and spawning data available for the upstream tributaries of Lake Oroville. In order to estimate the number of anadromous salmon whose passage to upstream tributaries and subsequent nutrient transfer was blocked by the Oroville Facilities, historical escapement data collection will focus on the time period between 1944 (construction of the tributary dams) and 1963 (completion of the Oroville Facilities).

Agency reports and data relating to the escapement of salmonids from the tributaries upstream of Lake Oroville will be collected, reviewed, and summarized. The review will incorporate historical investigations by federal and state agencies, peer-reviewed literature focusing on the Feather River system, and creel census reports. A wealth of information may also be available within the reports and information, which formed the basis of the mitigation programs relating to the Oroville facilities. Specifically, the escapement estimates from the upper tributaries used to develop the initial Feather River Hatchery production goals will be investigated.

Some of the data collected before the construction of the Oroville Facilities may not be officially published in agency reports. Furthermore, because the time periods of concern for Task 1 extends to over 50 years ago, some agency reports and data may have been transferred to a storage facility. For these reasons, natural resource professionals at various agencies may be asked to scour their files, specifically attempting to identify all reports, data, or otherwise useful information which may be available in their offices. Interviews with long-time or retired agency personnel may also prove useful in locating agency reports and data, as well as provide anecdotal observational information regarding the upper tributaries of the Feather River. In addition to agency resources, regional newspaper articles may provide estimates of historical escapement. Interviews with private parties in the Central Valley, particularly local sportfishing guides, recreational fishing clubs, and long-time area residents may also aid in approximating the historical escapement levels. Additionally, oral interviews with elders and other knowledgeable members of the Native American community will be conducted as directed by SP-C1 and testimony regarding the historical escapement of anadromous salmonids will be incorporated when possible.

To adequately assess the historical escapement to the North Fork Feather River, a literature review will be conducted regarding the effectiveness of the Big Bend Dam fish ladder. Any information pertaining to the functionality of Big Bend Dam fish ladder prior to the construction of the Oroville Facilities will be reviewed and summarized. The historical escapement estimations may be corrected, if necessary, to reflect these findings.

The results of these investigations will be summarized and a range of historical escapement values will be developed. In Task 3 of this study plan, the escapement information will be converted to a range of nutrient delivery values, which will approximate the levels of nutrients and organic material historically delivered to the upper tributaries.

Task 2— Estimate the potential maximum escapement of salmonids given the existing habitat of the tributaries upstream of Lake Oroville

Task 2 will evaluate the potential for spawning of Chinook salmon in the upstream tributaries. Essentially, Task 2 will provide an escapement estimate, which assumes that the Oroville Facilities did not block the passage of spawning anadromous salmonids into the upstream tributaries. The estimated escapement of Chinook salmon will be calculated using information collected in SP-F3.1 and SP-F10.

Task 1C of SP-F3.1 will identify available Chinook spawning habitat in the upstream tributaries from the Lake Oroville high water mark to the first upstream migration barrier. GIS coverages of habitat components will be developed to estimate the location, extent and relative qualities of habitat. Suitable spawning habitat locations will be determined by combining the habitat component coverages to identify areas with the combinations of habitat characteristics that fit the profile of Chinook salmon spawning habitat preferences. Habitat components will be combined from other study plans to identify suitable habitat including:

- mesohabitat maps provided by SP-G1;
- substrate characterization, transect data, channel morphology, assessment of woody debris, and cover cross-sectional monitoring data including water depth, velocity, and turbidity obtained from SP-G1;
- inundation flow boundaries at various flow levels interpolated from SP-G1 channel transects;
- vegetation survey results (grass, shrub, bush, tree classes) obtained from SP-T4;
- water temperature data obtained from SP-W6;
- water quality data obtained from SP-W1;
- exceedances of water quality recommendations for freshwater aquatic life obtained from SP-W1.

GIS coverages will be constructed to illustrate the areas, which provide suitable habitat for Chinook salmon by applying habitat requirement characteristics against the existing habitat condition attributes. A total estimated area of suitable Chinook salmon spawning habitat will be calculated by summing all of the areas, which meet the spawning habitat criteria.

Task 2B of SP-F10 will provide spawning density estimates for Chinook salmon in the Feather River downstream of Lake Oroville. Because a majority of the Chinook salmon spawning in the Feather River occurs between the Fish Barrier Dam and the Thermalito Afterbay Outlet, this task will capture the spawning densities from the surveys focused between these locations. Escapement of naturally spawned Chinook salmon will be estimated using carcass mark-recapture procedures outlined in Taylor (1974). The sizes of each riffle section where carcasses have been observed in the course of each sampling week will be calculated by estimating the spawning area from aerial photographs or by real-time kinematic (RTK) GPS survey of the spawning area boundaries. The spawning densities will then be calculated by determining the number of spawned Chinook salmon (estimated in the carcass survey) per unit area of adjacent riffles.

The potential maximum escapement of Chinook salmon into the upper tributaries will be approximated as the product of the spawning habitat availability in the upstream tributaries (SP-F3.1) and the spawning adult utilization per unit of available habitat in the Feather River downstream of the Oroville Facilities (SP-F10). Spawning density averages of other river systems from a literature review will also be calculated to estimate an average spawning density utilization. This method of escapement calculation assumes full utilization at a range of spawning densities of the available habitat of the upstream tributaries. While the escapement number derived in this fashion will be a rough estimate, it will allow for the development of a baseline reference from which to evaluate potential future PM&Es.

Although Task 1C of SP-F3.1 will only provide habitat data for the upstream tributaries above Lake Oroville's high water mark, an estimate of the escapement potential for the water fluctuation and permanent inundation zones of Lake Oroville will also be calculated. These estimates will be interpolated as the product of the estimated escapement of anadromous salmonids per river mile in the upstream tributaries and the length of the historic river channel within the water fluctuation and permanent inundation zones. The escapement potential of these zones will not only allow for a straightforward comparison between the escapement estimates provided by Task 1 and 2, but may also prove useful when designing potential PM&Es. If similar interpolations are required for tributary reaches above the identified upstream migration barrier (Task 1A of SP-F3.1), such calculations will be made under the cumulative analysis (SP-F12).

Task 3— Document, review, and summarize the existing literature regarding the types and amounts of nutrients and organic matter supplied by salmonid spawning and the nutrient transfer strategies from other investigations.

Published literature regarding the types and amounts of nutrients and organic matter derived from salmonid carcasses and spawning byproducts will be collected, reviewed, and summarized. While some information may be found in federal and state agency reports, a majority of the necessary information will likely be obtained through a peer-reviewed literature search. The results of the summary will likely identify a range of characteristic properties of salmonid-derived nutrients. A matrix will be constructed which will include the types of salmonid-derived nutrients and the range of amounts of each type of nutrient supplied per unit of salmonid biomass. The matrix will be used to determine the amount of each nutrient type that was or could be supplied by the escapement levels estimated in Tasks 1 and 2. In this manner, total nutrient and organic matter totals for the upstream tributaries will be estimated. This information will serve as a benchmark for development and evaluation of potential future PM&Es.

Task 3 will also identify the nutrient transfer strategies from other investigations, including mitigation methodologies, results of mitigation and monitoring programs, and the potential issues associated with nutrient transfer strategies. Many of the examples of nutrient transfer strategies are expected to be supplied from studies within the Pacific Northwest, although special effort will be given to identifying examples from the Central Valley and other parts of California. The nutrient transfer strategies will be reviewed and summarized, specifically relaying the various methodologies utilized by past projects, and the results of each restoration technique. The summaries will provide useful information when identifying the potential to conduct PM&Es in the upper tributaries.

6.0 Results and Product/Deliverables

Results

Results will be organized following the task headings. Each task will include a narrative summary of the relevant literature review and findings as well as tables, figures and maps summarizing the key points. The results of the three sections will be integrated to provide the tools needed to develop and evaluate potential future PM&Es relating to the upstream transfer of nutrients to ecosystems upstream of Lake Oroville. The anticipated maps, graphical representation of reviewed data (e.g., charts, and graphs) and summary figures and tables include:

- Chinook Narrative summary and appropriate graphics and tables from historical (1944-1963) escapement reports including technical agency documents, unpublished agency data, newspaper articles, and interviews with sporting clubs, agency personnel, and long-time area residents (Task 1);
- Figures, tables, calculations, assumptions, and narratives summarizing the results of the escapement estimate derived from the integration of current habitat availability in the upstream tributaries and current spawning densities in the Feather River downstream of the Oroville Facilities (Task 2);
- Figures, tables, calculations, assumptions, and narratives summarizing the results and methods of the conversion of the escapement estimates (provided in Tasks 1 and 2) to the total salmonid-derived nutrient and organic matter which was/could be supplied to the upstream tributaries (Task 3);

- Narrative summary and appropriate graphics and tables relating to the methods, results, and potential issues associated with the nutrient mitigation measures attempted in the Central Valley, California, and the Pacific Northwest (Task 3).

Products/Deliverables

The study plan summary report will include:

- Chinook Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- Introduction
- Methodology
- Narratives of relevant findings by task
- Discussion addressing most relevant questions (see above) and indicating any complications/data concerns
- Conclusions related to study plan goals and objectives
- References
- Appendices

7.0 Coordination and Implementation Strategy

Coordination with Other Resource Areas/Studies

It is anticipated that this study will require coordination with those individuals responsible for collecting the field data associated with the upstream tributaries spawning habitat mapping and the spawning densities of Chinook salmon from the Feather River downstream of the Oroville Facilities.

Given the nature of the tasks of this study, contacts with work groups directing and conducting other studies relevant to the Oroville Facilities FERC Relicensing Project are also expected. A list of study plans that will be related to the development of the present study includes:

- SP-F3.1 Evaluation of Project Effects on Resident Fish and their Habitat within Lake Oroville, its upstream tributaries, the Thermalito Complex, and the Oroville Wildlife Area

Task 1A of SP-F3.1 will identify the migratory barriers in the upper tributaries to be used to define the study area of this study plan. Task 1C of SP-F3.1 will identify the available Chinook spawning habitat to be used in estimating the escapement potential for the upstream tributaries in Task 2 of this study plan. Suitable spawning habitat locations will be determined by combining the GIS habitat component coverages to identify areas with combinations of habitat characteristics that fit the profile of Chinook salmon habitat preferences. Habitat components will be combined from other study plans to identify suitable habitat including:

- mesohabitat maps provided by SP-G1;
- substrate characterization, transect data, channel morphology, assessment of woody debris, and cover cross-sectional monitoring data including water depth, velocity, and turbidity obtained from SP-G1;

- inundation flow boundaries at various flow levels interpolated from SP-G1 channel transects;
- vegetation survey results (grass, shrub, bush, tree classes) obtained from SP-T4;
- water temperature data obtained from SP-W6;
- water quality data obtained from SP-W1;
- exceedances of water quality recommendations for freshwater aquatic life obtained from SP-W1.

GIS coverages will be constructed to illustrate the areas, which provide suitable habitat for Chinook salmon by superimposing the habitat requirement coverages over the existing habitat conditions. A total estimated area of suitable Chinook salmon habitat will be calculated by summing all of the areas, which meet the predetermined habitat criteria.

- SP-F10 Project Effects on Anadromous Salmonids and their Habitat

Task 2B of SP-F10 will provide spawning density estimates for Chinook salmon in the Feather River downstream of Lake Oroville to be used in estimating the escapement potential in the upstream tributaries in Task 2 of this study plan. Escapement of naturally spawned Chinook salmon will be estimated using carcass mark-recapture procedures outlined in Taylor (1974). The sizes of each riffle section where carcasses have been observed in the course of each sampling week will be calculated by estimation of spawning area from aerial photographs or by real-time kinematic (RTK) GPS survey of the spawning area boundaries. The calculated riffle sizes will be added to produce estimates of weekly or monthly spawning areas in the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet. The spawning densities will then be calculated by determining the number of spawned Chinook salmon (estimated in the carcass survey) per unit area of adjacent riffles.

- SP-C1-Cultural Resources Inventory

SP-C1 will provide results of oral interviews with elders and other knowledgeable members of the Native American community regarding cultural and historical resources. Relevant information from oral interviews regarding the historical escapement of anadromous salmonids will be incorporated into SP-F8.

Issues, Concerns, Comment Tracking and/or Compliance Requirements

Stakeholder Issues Fully Addressed by the *Transfer of Energy and Nutrients by Anadromous Fish Migrations* Study Plan

Issue	Description
FE29	Protection of upstream resources energy balance issues—historic uses salmon-steelhead moving upstream—biomass——nutrient dispersal.
FE82	Prior to construction of Oroville Dam anadromous fish had access to the POE reach of the North Fork Feather River. These fish provided a source of energy to the river ecosystem. Construction of the dam severed that connection. There is an interest in determining the contribution of anadromous fish as an energy source for aquatic dependent species located in the North Fork Feather River and devising a strategy for replacing this loss.

Source: National Environmental Policy Act (NEPA) Scoping Document 1 and California Environmental Quality Act (CEQA) Notice of Preparation. DWR 2001.

8.0 Study Schedule

	Timing/Deadlines		
Task	**Data collection/analysis occurring in SP-F8**	**Interim Report**	**Final Report**
1	Document, review, and summarize the available literature regarding historical escapement of anadromous salmonids into the tributaries upstream of Lake Oroville	N/A	To be complete within three months after the necessary data from SP-3.1 and SP-F10 become available
2	Estimate the potential maximum escapement of Chinook salmon given the existing habitat of the tributaries upstream of Lake Oroville		
3	Document, review, and summarize the existing literature regarding the types and amounts of nutrients and organic matter supplied by salmonid spawning		
	Document, review, and summarize the nutrient transfer strategies from other investigations		

9.0 References

In addition to the references cited in Section 5.0, a complete list of references used in the completion of the study will be part of the summary report. The references cited in the present plan are listed below.

Bilby, R. E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53:64-73.

Cederholm, C. J., M.D. Kunze, T. Murota, and A. Sibitani. 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10):6-15.

DWR Environmental Services Office. October 1993. Lake Oroville Fisheries Management Plan. Progress Report.

DWR. 2001. Initial Information Package, Relicensing of the Oroville Facilities, January 2001.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historic and current levels of salmon production in the northeast Pacific ecosystem: evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries 25(1): 15-21.

Taylor, S. N. (ed.) 1974. King (Chinook) salmon spawning stocks in California's Central Valley, 1973. California Department of Fish and Game, Rep. No 74-12, 32 pp.